# Predicting the Need for Surgical Intervention Prior to First Encounter for Individuals With Knee Complaints

## A Novel Approach

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**Background:** Orthopaedic complaints, particularly those relating to the knee, are some of the most common conditions that bring patients to the hospital. Many patients bypass their primary care physician to seek the care of an orthopaedic surgeon without referral, leaving the surgeon to manage an increasingly large number of patients, many of whom will never require surgery.

**Purpose:** To develop a brief questionnaire that can be administered via phone/web at the time of appointment request to predict an individual patient's probability of requiring surgical intervention.

**Study Design:** Case-control study; Level of evidence, 3.

**Methods:** All patients (N = 1307) seeking an appointment for a new knee-related complaint completed a branching-logic questionnaire. A retrospective chart review was conducted following the conclusion of each patient's episode of care to determine whether surgery was recommended. Logistic regression models were used to predict the risk of surgery based on triage question responses, basic demographics (age, sex), and laterality (unilateral vs bilateral). The ability of the models to discriminate between those who did and did not receive a surgical recommendation was measured with a concordance index.

**Results:** The model provided a high level of discrimination between surgical and nonsurgical cases (concordance index, 0.69). Recent injury with inability to walk and no recent injury with no pain were both associated with an increased probability of receiving a recommendation of surgical intervention as compared with patients who reported pain without recent injury (odds ratio [OR]: 3.51 [$P < .001$] and 2.78 [$P = .008$], respectively). A unilateral complaint was associated with needing surgical intervention (OR, 4.52 [$P < .001$]). Age had a significant nonlinear relationship with odds of needing of surgery, with middle-aged patients (range, 20-50 years) having the greatest odds.

**Conclusion:** The current model, which utilizes demographic questions and portions of a routine history alone, was able to accurately identify individuals who are most likely (up to 65% probability) and least likely (<5% probability) to need knee surgery. This model can quickly and easily conduct triage at the time of appointment request to ensure that patients with the highest likelihood of receiving a recommendation for surgical intervention are seen by surgical providers, while those who are unlikely to receive such a recommendation can be seen by nonsurgical providers.

**Keywords:** knee; scheduling; triage; surgical risk; predictive modeling

Each year, billions of individuals worldwide suffer from musculoskeletal complaints, and millions of Americans visit the orthopaedic surgeon's office with a musculoskeletal complaint.[4] In 2012 alone, nearly 50 million orthopaedic surgery–related visits occurred in the United States, ranking orthopaedic visits fifth among all types of visits, behind only general and family practice, pediatrics, internal medicine, and obstetrics and gynecology.[2] St Sauver and colleagues[9] reported that musculoskeletal complaints as a whole (including osteoarthritis, joint pain, and back pain) were cited as the reason for seeking a doctor's appointment in over 57% of patients.

In 2012, knee symptoms alone were the seventh-most common reason for visiting the doctor's office (including all specialties), listed as the principal reason for the patient's visit in over 14 million encounters.[1] When we consider the reason for visiting an orthopaedic surgeon specifically, the burden of knee complaints is magnified, as knee-related issues were the most common reason given by patients for visiting an orthopaedic surgeon.[2] As the population continues to age and as access to care improves, we can and should expect the demand for orthopaedic care to continue

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to grow. For example, in 2014 more than 1 in 4 American adults reported joint pain lasting longer than 3 months.[3]

Orthopaedics not only represents a large portion of office visits, but it also makes up a significant portion of surgical interventions. As of 2012, procedures involving muscles and tendons ranked second among all ambulatory surgical procedures performed in community hospitals, whereas surgical procedures related to orthopaedics (excluding those involving the spine) represented 17.8% of all ambulatory surgical procedures.[11]

Thus, there is not only a large demand for orthopaedic attention but also an equally imposing demand for the surgical expertise of orthopaedic surgeons. Despite the number of operations performed however, the majority of patients seeking an appointment for a musculoskeletal complaint are treated nonoperatively. While primary care physicians can sometimes gauge the severity of a patient's complaint and appropriately refer him or her to a surgical or nonsurgical provider, at least 47% and up to 60% of the 50 million orthopaedic office visits that occurred in 2012 took place without a referral from a primary care physician.[1] This finding indicates that a huge number of patients are left to assess the severity of their condition and seek appropriate attention from a surgical or nonsurgical provider by themselves.

Aside from any assurance that the provider with which patients have been scheduled is appropriate with respect to subspecialty (upper extremity, hip/knee, foot/ankle, etc), patients undergo no formal method of triage to ensure that those with the highest likelihood of needing surgical intervention are seen by surgeons and those with very little chance of requiring an operation are seen by nonoperative providers. As a result, those with the highest likelihood of needing surgery are given the same priority as those who are almost guaranteed to need no such intervention. Consequently, those patients with little likelihood of needing surgery may fill up the appointment slots of surgical providers, while those who have a greater chance of requiring a surgical intervention are delayed by seeing a nonsurgical specialist, only to be evaluated, diagnosed, and then referred to a surgical colleague. Both instances are frustrating, time consuming, and costly for all parties involved.

In a proactive attempt to more efficiently handle the increasing demand for orthopaedic attention, we developed a triage questionnaire based on branching logic and utilized it prospectively to more appropriately schedule patients according to individual likelihood of needing surgery. To our knowledge, the prospective triage questionnaire presented here represents the first of its kind that can be administered quickly and easily over the phone (or by web-based system) by scheduling staff to estimate a patient's probability of requiring a surgical intervention.

## METHODS

The branching-logic triage questionnaire used in this study (Figure 1) was developed by the senior author (K.P.S.). The questionnaire was prospectively administered to all patients (N = 1307) seeking a knee-related appointment with a sports health provider within the Department of Orthopaedics at the Cleveland Clinic between January 1, 2015, and June 1, 2015. Upon calling to schedule an appointment, patients were asked a series of, at most, 8 questions. Regardless of the results of the questionnaire, patients were scheduled for the appointment slot convenient to them unless advised to visit the nearest emergency department. Patients went on to receive care as would normally occur, with the care providers kept blinded to the results of the triage questionnaire.

A retrospective chart review of the same 1307 patients, to determine whether patients were recommended to undergo or in fact underwent surgery, was completed by one of the authors (J.F.V.), who was also kept blinded to the results of the triage questionnaire. Of the 1307 patients who completed the questionnaire, 327 never progressed to an appointment, owing to appointment cancellation or no-show; 51 attended an appointment but had not been given a definitive treatment plan, or a treatment plan was not included in the chart; and 9 patients called more than once within 1 month for evaluation of the same complaint. In this case, only the last call within the month was kept in the analysis data set. Exclusion of these individuals left 920 records for 912 unique patients. Those younger than 13 years and those older than 75 years were also excluded, leaving 854 records in 846 unique patients.

The data points collected from the chart for use in model development included laterality (unilateral vs bilateral) and treatment plan (surgery vs other). The treatment plan that was recommended to the patient, whether or not she or he adhered, was recorded as the final treatment plan.

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Ethical approval for this study was waived by the Cleveland Clinic Institutional Review Board.

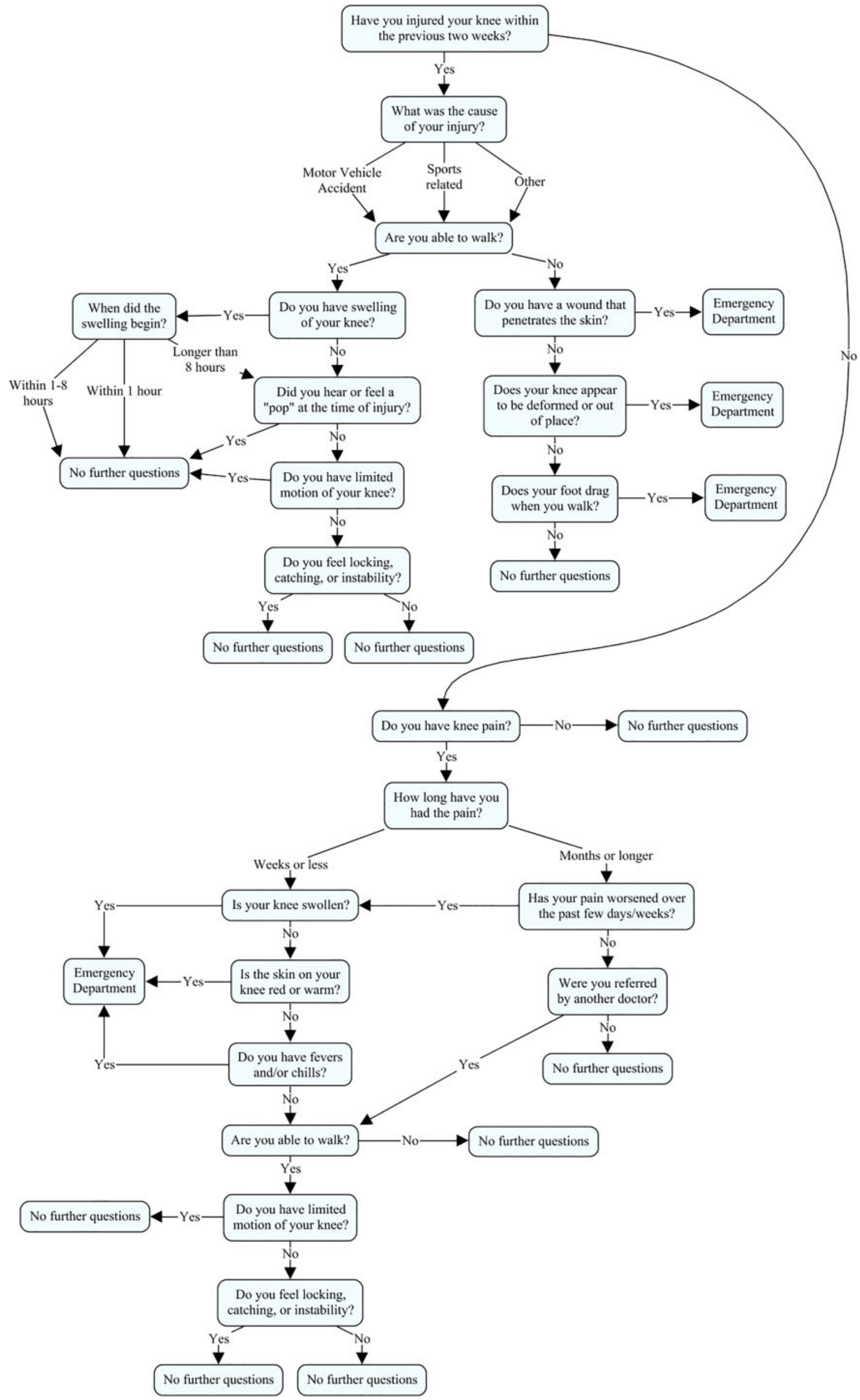


**Figure 1.** Flowchart of complete triage questionnaire.

Patients who underwent surgery after failure to improve despite conservative therapy—which included physical therapy, anti-inflammatory medications, and/or intra-articular injections—were grouped with patients who underwent surgery without a prior attempt to manage symptoms with conservative treatment modalities.

TABLE 1
Comparison of Patients Included and Excluded From the Final Data Set[a]

| Factor | Overall (N = 1307) | Excluded (n = 453) | Final Data (n = 854) | *P* |
|---|---|---|---|---|
| Age at time of appointment, y | 34.7 ± 18.9 | 32.5 ± 220.6 | 35.8 ± 17.8 | .69[b] |
| Sex | | | | .16[c] |
| Male | 702 (53.7) | 231 (51.0) | 471 (55.2) | |
| Female | 605 (46.3) | 222 (49.0) | 383 (44.8) | |
| Level 1 | | | | |
| Recent injury | 496 (37.9) | 168 (37.1) | 328 (38.4) | .63[c] |
| No recent injury | 811 (62.1) | 285 (62.9) | 526 (61.6) | |
| Level 2 | | | | |
| Injury and walking | 428 (32.7) | 151 (33.3) | 277 (32.4) | .76[c] |
| Injury and not walking | 68 (5.2) | 17 (3.8) | 51 (6.0) | .086[c] |
| No recent injury and pain | 758 (58.0) | 264 (58.3) | 494 (57.8) | .85[c] |
| No recent injury/ no pain | 53 (4.1) | 21 (4.6) | 32 (3.7) | .46[c] |

[a]Values presented as mean ± SD or n (% for the column).
[b]Mixed model.
[c]Logistic regression with generalized estimating equations.

TABLE 2
Comparisons of Age, Sex, Laterality, and Triage Questionnaire Response on Risk of Receiving a Recommendation for Surgical Intervention[a]

| Factor | No Surgery (n = 655) | Surgery (n = 199) | *P* |
|---|---|---|---|
| Age at time of appointment, y | 36.8 ± 18.5 | 32.4 ± 14.7 | .002[b] |
| Sex | | | .32[c] |
| Male | 355 (75.4) | 116 (24.6) | |
| Female | 300 (78.3) | 83 (21.7) | |
| Bilateral involvement | | | <.001[c] |
| No | 553 (74.2) | 192 (25.8) | |
| Yes | 102 (93.6) | 7 (6.4) | |
| Level 1 | | | |
| Recent injury | 237 (72.3) | 91 (27.7) | .013[c] |
| No recent injury | 418 (79.5) | 108 (20.5) | |
| Level 2 | | | |
| No recent injury and pain | 400 (81.0) | 94 (19.0) | <.001[c] |
| Injury and walking | 211 (76.2) | 66 (23.8) | |
| No recent injury/no pain | 18 (56.3) | 14 (43.8) | |
| Injury and not walking | 26 (51.0) | 25 (49.0) | |

[a]Values presented as mean ± SD or n (% for the row).
[b]Linear mixed effect model.
[c]Logistic regression with generalized estimating equations.

TABLE 3
C-indexes and Included Variables for Model 6 and Model 9[a]

| Model | Factors | C-index |
|---|---|---|
| 6 | Injury status, walking, pain, age, bilateral | 0.69 |
| 9 | Injury status, walking, recent pain, swelling, age, bilateral | 0.70 |

[a]C-index, concordance index.

Multivariable logistic regression modeling was used to predict the risk of surgery based on triage question responses, basic demographics (age and sex), and laterality of the complaint (unilateral vs bilateral). Age was included in the model as a nonlinear effect with restricted cubic splines with 3 knots. After the models were fit, the ability of the models to discriminate between patients recommended for surgery versus not recommended for surgery was measured with a concordance index (C-index). Bootstrap resampling was performed to bias correct this estimate. Similar methods were used to evaluate the calibration of the model (agreement between predicted and actual risk). Analyses were performed with R software (v 3.1).

This project was granted exemption by the Cleveland Clinic's institutional review board.

## RESULTS

Table 1 shows the overall comparisons of patients who were in the final data set and those who were excluded. The 2 groups were similar in all respects, although the difference in likelihood of a patient who reported injury and inability to walk to undergo an assessment approached significance ($P$ = .086).

After exclusion of patients who were never presented with a treatment plan (owing to appointment cancellation, no-show, or treatment plan yet to be determined), those who underwent or were advised to undergo surgery—including those who failed to improve despite initial attempts to treat their symptoms with at least 4 to 6 weeks of conservative measures and were then advised to undergo surgery—were compared with those who were prescribed a nonsurgical treatment plan (ie, at no point was a surgical intervention presented to the patient as a treatment option) to determine which variables would be included in the models (Table 2). Of the variables assessed through multivariable analysis, only sex was found not significantly predictive of likelihood of needing surgery ($P$ = .32) and thus was not included in the final model. When compared with those who were not advised to undergo surgery, patients who underwent or were advised to undergo surgery tended to be younger (mean ± SD: 32.4 ± 14.7 vs 36.8 ± 18.5 years; $P$ = .002) and more likely to have a unilateral complaint (odds ratio [OR] = 5.06, 95% CI = 2.31-11.07; $P < .001$).

Nine unique models were developed to estimate the risk of an individual patient's requiring surgical intervention. The 2 models with the highest C-indexes are shown in Table 3 with their respective variables. The C-index represents the rate at which a model correctly assigns a higher likelihood of needing surgery to a patient who ultimately underwent or was advised to undergo surgery when compared with a patient

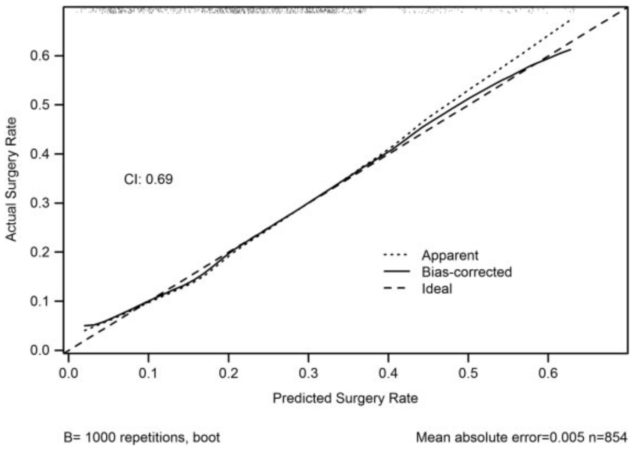


**Figure 2.** Calibration plot of model 6. The graph compares the predicted rate of surgery as determined by the model with the actual rate of surgery.

TABLE 4
Odds Ratios for Model 6 Including 2 Scheduling Questions, Age, and Bilateral Status

| Variable: Level | Odds Ratio | 95% CI | *P* |
|---|---|---|---|
| Intercept | 0.02 | 0.01-0.06 | <.001 |
| Response category | | | |
| No recent injury/pain: yes | 1.00 | Reference | |
| Injury and walking: yes | 1.19 | 0.82-1.72 | .37 |
| Injury and not walking: yes | 3.51 | 1.87-6.57 | <.001 |
| No recent injury/no pain: yes | 2.78 | 1.30-5.93 | .008 |
| Age at time of appointment | | | |
| Linear | 1.06 | 1.03-1.09 | <.001 |
| Nonlinear | 0.89 | 0.85-0.93 | <.001 |
| Bilateral involvement: unilateral | 4.52 | 2.04-10.02 | <.001 |

who was prescribed a nonoperative treatment plan. A C-index of 0.5 reflects assignment by chance.

Model 6—which included injury status (yes/no), walking status (able/unable), pain (yes/no), age, and laterality (unilateral/bilateral)—provided a high level of discrimination between surgical and nonsurgical cases (C-index = 0.69) while needing fewer questions (4 total questions; patient maximum: 3 questions, not including age) compared with model 9 (5 total questions; patient maximum: 4 questions, not including age), which yielded slightly better discriminative capabilities (C-index = 0.70). See Figure 2 for the calibration plot corresponding to model 6.

Table 4 lists the OR corresponding to each possible response to the triage questionnaire, age at time of appointment, and bilateral involvement after inclusion in the model. The odds of requiring surgical intervention were greater in patients reporting a recent injury and an inability to walk when compared with those who reported no recent injury and pain (OR = 3.51, 95% CI = 1.87-6.57; $P < .001$). Similarly, reporting no recent injury and no pain

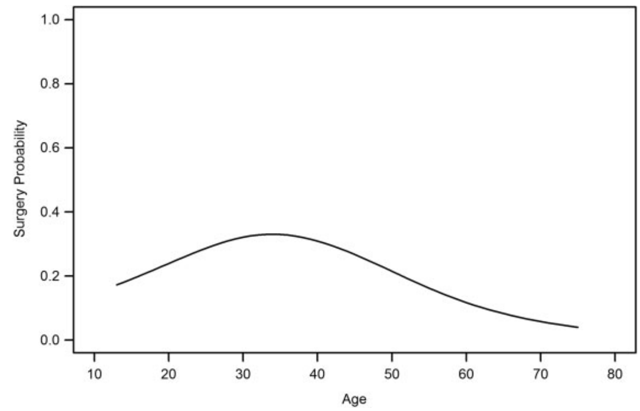


**Figure 3.** Predicted likelihood of surgery for a patient with unilateral pain and no acute injury.

was also associated with increased odds of requiring surgery when compared with the same reference group (OR = 2.78, 95% CI = 1.30-5.93; $P = .008$).

Age and unilateral complaint were both found to be significantly associated with receiving a recommendation to undergo surgical intervention. Patient age had a significant nonlinear relationship with odds of undergoing surgery, with middle-aged patients (20-50 years) having the greatest odds. This is demonstrated in Figure 3, which displays the likelihood of surgery by age for a patient reporting unilateral pain with no acute injury (Figure 3). The shape of the curve remained constant in the other scenarios, simply shifting higher or lower depending on the other variables. The odds of receiving a recommendation to undergo surgery for a patient with a unilateral complaint were significantly greater than the odds for a patient with a bilateral complaint (OR = 4.52, 95% CI = 2.04-10.02; $P < .001$).

Table 5 is a version of the nomogram corresponding to model 6. Each risk factor that is included in the predictive algorithm is displayed with its corresponding point value for a given response. The risk of requiring a surgical intervention as calculated by the model is shown with the corresponding total point value. The traditional depiction of model 6 as a nomogram is shown in Figure 4.

## DISCUSSION

Triage systems, such as the one presented here, are neither new nor unique to medicine. Although much of the triage in modern medicine is based on clinical judgment, empirically validated triage systems are slowly becoming more prevalent in settings such as the intensive care unit.[7] Perhaps the most obvious example of triage is that which occurs in the emergency department. Most emergency departments in the United States utilize the Emergency Severity Index to assign patients a severity score ranging from 1 to 5, with 1 indicating that the patient requires immediate medical attention and 5 indicating that the patient can be seen within 2 to 24 hours with minimal risk.[6,8] Despite being an easy-to-use tool, the Emergency Severity Index requires a physical interaction

TABLE 5
Summary of Point Distribution for Model 6

| Variable: Level | Points |
| --- | --- |
| Not injured/pain: yes | 0 |
| Injured and walking: yes | 7 |
| Injured/not walking: yes | 51 |
| Not injured/no pain: yes | 41 |
| Age, y | |
| 10 | 58 |
| 15 | 70 |
| 20 | 82 |
| 25 | 92 |
| 30 | 98 |
| 35 | 100 |
| 40 | 96 |
| 45 | 88 |
| 50 | 76 |
| 55 | 62 |
| 60 | 47 |
| 65 | 31 |
| 70 | 16 |
| 75 | 0 |
| Bilateral: no | 61 |
| **Total Points** | **Surgical Risk** |
| 3 | 0.01 |
| 71 | 0.05 |
| 101 | 0.10 |
| 134 | 0.20 |
| 190 | 0.50 |
| 246 | 0.80 |

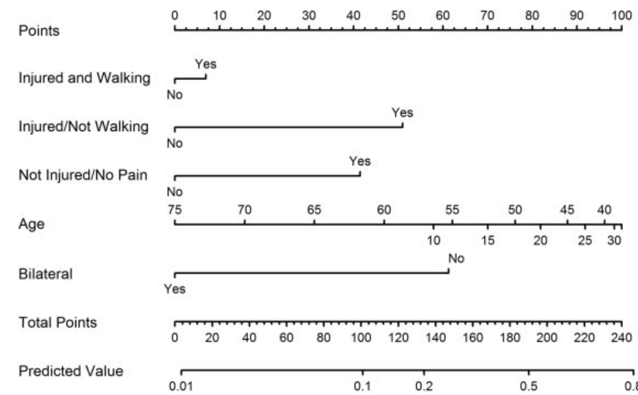


**Figure 4.** Model 6 nomogram.

between the triage nurse and the patient. Our triage questionnaire is unique in that it is used before the patient presents to the physician's office, because it relies exclusively on simple yes/no questions that have been shown to be associated with knee pathology and it does not require a physical examination.[5,10] To our knowledge, no other such method of triage has been developed and validated for use in the clinical setting.

The triage model developed here allows for the rapid estimation of a patient's risk of requiring knee surgery before he or she sets foot into the provider's examination room. Our model is capable of identifying patients who have a high probability (up to 65%) of ultimately undergoing knee surgery. This represents a substantial improvement over the current method of scheduling, which allocates appointment slots based on physician availability and patient preference without regard for acuity, as the incidence of surgical intervention in our cohort was only 23.3%. Likewise, our model is also capable of identifying patients with the lowest risk of receiving a recommendation to undergo a surgical intervention (<5%). Together, these 2 capabilities will allow for more efficient and appropriate scheduling of patients.

To better understand the model and how to use it, consider the following pair of examples. Each hypothetical encounter begins with patients reporting their age and whether their problem is with 1 knee in particular or both knees. Then, patients are asked whether they have experienced an acute injury within the previous 2 weeks (possible answers being yes or no). Those who answer yes are then asked about their ability to walk (again, possible answers being yes or no). Those who deny a history of injury within the previous 2 weeks are instead asked about the presence of knee pain (again, possible answers being yes or no). The result is 1 of 4 possible combinations: (1) injured and able to walk, (2) injured and unable to walk, (3) uninjured with knee pain, or (4) uninjured without knee pain. At the end of this brief line of questioning, the patient's likelihood of needing surgery (or, rather, receiving a recommendation to undergo surgery for a knee problem) can be calculated. Consider a 35-year-old patient requesting an appointment who reports an acute unilateral injury within the previous 2 weeks and an inability to walk. Reporting injury and inability to walk gives this patient 51 points (calculated either with Table 5 or by drawing a vertical line from the correct response group through the "points line" in Figure 4), while his or her age corresponds to an additional 100 points. Finally, a unilateral complaint is worth 61 additional points, for a total of 212 points. This corresponds to an approximately 65% chance of needing surgery (again, calculated either with Table 5 or by drawing a vertical line from the total points through the "predicted value" line of Figure 4). Conversely, consider a 55-year-old patient who complains of bilateral knee pain but reports no recent injury. No recent injury/pain is given 0 points, while age 55 years corresponds to 62 additional points. A bilateral complaint is also worth 0 points, giving this patient a total of 62 points. This corresponds to a <5% chance of needing surgery.

According to our model, a patient who requests an appointment and denies both recent injury and pain is also at an increased risk for receiving a recommendation to undergo surgery as compared with patients who report pain without recent injury. While this seems very counterintuitive, we believe that this portion of our cohort represents patients who were evaluated at an outside institution and referred to us specifically for surgical evaluation. Of the 32 patients who denied both injury and pain when completing the triage questionnaire, 17 (53%) reported a history of acute injury that occurred more than 2 weeks prior to their appointment request (at which time they would have been asked about acute injury within the previous 2 weeks). Many of the remaining patients in this subsection of our cohort were evaluated at other institutions and given preliminary diagnoses before requesting an appointment at our institution either for second opinions or for definitive surgical management. This is in contrast to the patients who reported pain but denied recent injury, as the majority of them had no such history of acute injury at any time and (to our knowledge) were seeking their first medical evaluation with respect to their knee. We hypothesize that those patients who denied pain and recent injury experienced resolution of pain while being evaluated elsewhere and, as a result of the time delay, were requesting an appointment beyond the 2-week window in which we asked about acute injury.

The demand for orthopaedic evaluation continues to grow, placing increased strain on the time of the orthopaedic surgeon. While all patients deserve proper medical attention, some require attention more urgently than others. Use of our scheduling algorithm would allow physicians to authorize scheduling staff to add same-day or next-day appointments to already full schedules for those patients with the highest risk of needing surgery. The surgical risk threshold above which a same-day/next-day appointment slot can be added could be determined at an institutional level or even at the individual level, with each physician setting his or her own threshold for the addition of same-day/next-day appointment slots. We believe that use of our model in this fashion would help patients begin the journey to recovery sooner.

This model could provide valuable information not only to physicians and scheduling staff but also to patients. After completion of the brief questionnaire, patients could be presented with their risk of requiring a surgical intervention as calculated by the model and then allowed to choose for themselves whether to schedule an appointment with a surgical or nonsurgical provider. This could help patients mentally prepare for the possibility of needing surgery (for those in the high-risk groups) or accept that surgery is an unlikely option (for those in the lowest-risk groups). Both scenarios may help to increase patient satisfaction while reducing the time that it takes for patients to see the appropriate provider, receive a diagnosis, and begin the proper treatment regimen.

In the development of our model, we evaluated only the occurrence of surgery within 6 months of the index encounter. Consequently, our results may underestimate the true need for surgical intervention, as some patients may fail to see an improvement in symptoms within the 6-month window and undergo surgery at a later date. Thus, some of the patients in our cohort who were considered nonoperative may ultimately cross over and become surgical patients. We also cannot comment on the appropriateness of the surgical procedures performed or the surgical recommendations made, but this study was conducted at an academic medical institution by salaried staff members, potentially reducing the risk of overestimated surgical recommendations.

Another limitation is that our questionnaire was developed per the experience and clinical expertise of the senior author. While we do not think that the questions are particularly difficult to interpret, we did not assess any psychometric properties of the questionnaire, such as test/retest reliability. It is possible that how one patient defines "injury" is different from another patient or the authors. It is also possible that some patients reported no pain because they did not experience pain at rest (eg, when on the phone waiting for a scheduler to become available). Again, while these possibilities exist, we do not believe that they significantly affected the results of the current study.

It is also worth noting that the current study developed the branching algorithm and internally validated it but did not externally validate it by using a separate data source. Although the use of bootstrap analysis creates additional data sets, it does so by randomly sampling the existing data set. Future validation studies should compare the ability of the algorithm to correctly discern surgical from nonsurgical cases with an entirely new cohort.

One potential modification that may improve the discriminatory powers of the current algorithm would be to explicitly ask patients if they have already undergone a diagnostic workup elsewhere that culminated in a final diagnosis. Doing so might decrease the portion of patients who deny recent injury (within 2 weeks) as well as pain but who go on to require surgery.

## CONCLUSION

We have developed a 4-question scheduling triage system that can quickly and easily estimate an individual patient's likelihood of receiving a recommendation to undergo a surgical intervention. Our system was capable of identifying patients with a likelihood of being advised to undergo surgery (probability as high as 65%), which represents a substantial improvement when compared with the likelihood of any given patient receiving the same recommendation of surgery (approximately 20% from our experience). Our system was also able to identify patients with a low likelihood of being given a surgical treatment plan (<5%). We believe that our system, as compared with traditional methods of scheduling patients, represents a significant improvement that will help to schedule patients with the appropriate provider sooner while improving patient and physician satisfaction and reducing cost. This system could also be used as a template for other areas of medicine that face similar scheduling difficulties. While already easy to use, the questions used in the current study could be packaged in a premade "calculator" so that risk of needing surgery can be determined more quickly by physicians and/or their scheduling staff.

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